reduction using a guard band and/or filtering would be required in all satellites placed in operation.

These and other techniques for allowing MSS/RDSS sharing with radio astronomy services will be more fully developed in the following subsections of this report.

5.1 MSS/RDSS Uplink Sharing

5.1.1 Fixed Protection Zones for In-Band MSS Transmissions

The discussion in this subsection is concerned with estimation of the approximate size of the areas surrounding radio telescopes that will be required to protect them from uplink emissions of MSS and RDSS terrestrial units operating co-channel in the primary radio astronomy band 1,610.6 to 1,613.8 MHz. The protection zone radii derived in this subsection do not apply to the case of the IRIDIUM system, in which the channels are all above 1,616 MHz, or to any other system with uplink channels completely above 1,613.8 MHz. Protection zone radii for IRIDIUM and other systems not directly emitting in the 1,610.6- to 1,613.8-MHz band will depend upon the level of unwanted emissions that fall below 1,613.8 MHz.

Two calculations, using different propagation models were performed.

1. The specified parameters of systems with channels in the radio astronomy band indicate that the EIRP spectral density values of the uplink transmissions, averaged over the channel bandwidths, fall mostly within the range 10^{-5} to 10^{-6} W/Hz. For the present calculations, a representative value of $3x10^{-6}$ W/Hz (-55 dBW/Hz) will be used.

   For the threshold of unacceptable interference for single antennas and close-spaced arrays, a value of -238 dBW/(m^2Hz) is obtained by interpolation from Table II of CCIR Report 224-7. For observations in the VLBI mode, a value of -200 dB(W/m^2Hz) is obtained from the pfd indicated in Figure 2 of Report 224-7 spread over 3.2 MHz, the width of the radio astronomy band.

   For propagation effects, the results of Okumura et al. (Review of the Electrical Communication Laboratory, 16, pp. 825–873, Sept.–Oct. 1968) are used. Figure 41(d) of this paper gives propagation curves for 1,500 MHz in urban areas for distances up to 100 km, and Figure 22 gives the correction to be subtracted from the path loss for propagation in open areas. This last correction is used because the radio astronomy observatories to be protected are not located in urban areas.

   The curve for antenna heights of 30 m and 1.5 m is taken as representative of a radio telescope and a vehicle-mounted antenna. Then, for a distance of 100 km (the maximum covered by the propagation data), the median spfd is -214 dB(W/m^2Hz), i.e., 24 dB above the unacceptable threshold for single antennas and close-spaced arrays. A rough extrapolation of the curve in Okumura et al. indicates that the mean spfd reaches the unacceptable threshold of -238 dB(W/m^2Hz) at a distance of 170 km (103.5 miles). For

VLBI observations, the mean spfd is equal to the unacceptable threshold for a distance of 50 km.

The values for the range at which the median signal is equal to the unacceptable threshold can be used as an indication of the sizes of the protection zones required, i.e., radii of 50 km for VLBA sites and 100 miles (160 km) for the other telescopes (Arecibo, Puerto Rico; Green Bank, West Virginia; the VLA near Socorro, New Mexico; and the Ohio telescope).

These figures provide a basis for discussion of the feasibility of implementing protection zones. More detailed information will lead to more reliable definition of the zones required. For example, the precise definition of a protection zone should be such that the sum of all transmissions outside of it do not exceed the appropriate unacceptable threshold at the radio astronomy site. Thus the expected density of users and the fraction of time they transmit are factors that should be included in a detailed calculation. Also, radio astronomy sites have been chosen to take advantage of shielding by terrain features whenever possible, and, in many cases, propagation is limited by diffraction over nearby ridges and mountains. To take advantage of this situation, propagation loss should be computed from the terrain contours for each site involved. Thus it will be advantageous to calculate protection zones individually for each site concerned and to use more exact MSS/RDSS system parameters when the systems to be implemented are known.

2. As an example of a site-dependent calculation, a small sample of MSS terrestrial unit locations for each of four radio observatory sites was selected to estimate the propagation losses from actual terrain contours. The calculations are based on the Longly-Rice model for irregular terrain, multiple diffraction obstacles, and troposcatter. The terrain path profiles were derived from a digital elevation map of 30 arcsec grid provided by the Defense Mapping Agency.

   Results listed in Table 5-1 and plotted in Figure 5-1 illustrate the wide range of distances which are necessary to achieve signal levels below the unacceptable threshold spectral power density at the four observatories (negative dB for SPD/HTSPD). Although the Green Bank Telescope (GBT), in the Allegheny Mountains of West Virginia, has several diffraction obstacles in the 138-km path from Roanoke, Virginia, a MSS signal from there is only 7 dB below the unacceptable threshold. Terrestrial units in the urban area of Phoenix, Arizona, from 150- to 200-km distant, exceed the unacceptable threshold at the VLBA Kitt Peak site by 12 to 22 dB. Figures 2 and 3 show the terrain profiles from Roanoke to the GBT and from Chandler, Arizona, to Kitt Peak.

Table 5-1. Power Densities and Spectral PDs at Radio Observatories from MSS Terrestrial Units

DISTANCE (km)	RATIO SPD/HTSPD (dB)	SPECTRAL PD @ RA OBS FROM -55 dBW/Hz TRANSMITTER (dBW/(m^2.Hz))	POWER DEN @ RA OBS FROM 0 dBW TRANSMITTER (dBW/(m^2))	TRANSMITTER LOCATION	RADIO OBSERVATORY
20	56	-182	-127	Frost	Green Bank Telescope, WV
35	1	-237	-182	Mtn Grove	Green Bank Telescope, WV
72	-43	-281	-226	Covington	Green Bank Telescope, WV
104	-31	-269	-214	Fincastle	Green Bank Telescope, WV
138	-7	-245	-190	Roanoake	Green Bank Telescope, WV
62	31	-207	-152	Riley	Very Large Array, NM
107	12	-226	-171	Sancha	Very Large Array, NM
142	7	-231	-176	ABQ Airport	Very Large Array, NM
154	24	-214	-159	ABQ NE Hgts	Very Large Array, NM
165	35	-203	-148	Sandia Crest	Very Large Array, NM
24	6	-194	-139	Wilton	VLBA-Hancock, NH
48	2	-198	-143	Nashua	VLBA-Hancock, NH
63	-7	-207	-152	Lowell	VLBA-Hancock, NH
79	-12	-212	-157	Bedford	VLBA-Hancock, NH
95	-21	-221	-166	Boston	VLBA-Hancock, NH
101	-16	-216	-161	Logan Airport	VLBA-Hancock, NH
40	-1	-201	-146	Manchester-W	VLBA-Hancock, NH
44	-3	-203	-148	Manchester-E	VLBA-Hancock, NH
61	38	-162	-107	Aguirre	VLBA-Kitt Peak, AZ
104	34	-166	-111	Casa Grande	VLBA-Kitt Peak, AZ
151	12	-188	-133	Chandler	VLBA-Kitt Peak, AZ
187	15	-185	-130	Scottsdale	VLBA-Kitt Peak, AZ
204	22	-178	-123	Cave Creek	VLBA-Kitt Peak, AZ

Harmful threshold SPD (HTSPD) = -238 dBW/(m^2.Hz) for GBT & VLA
= -200 dBW/(m^2.Hz) for VLBA

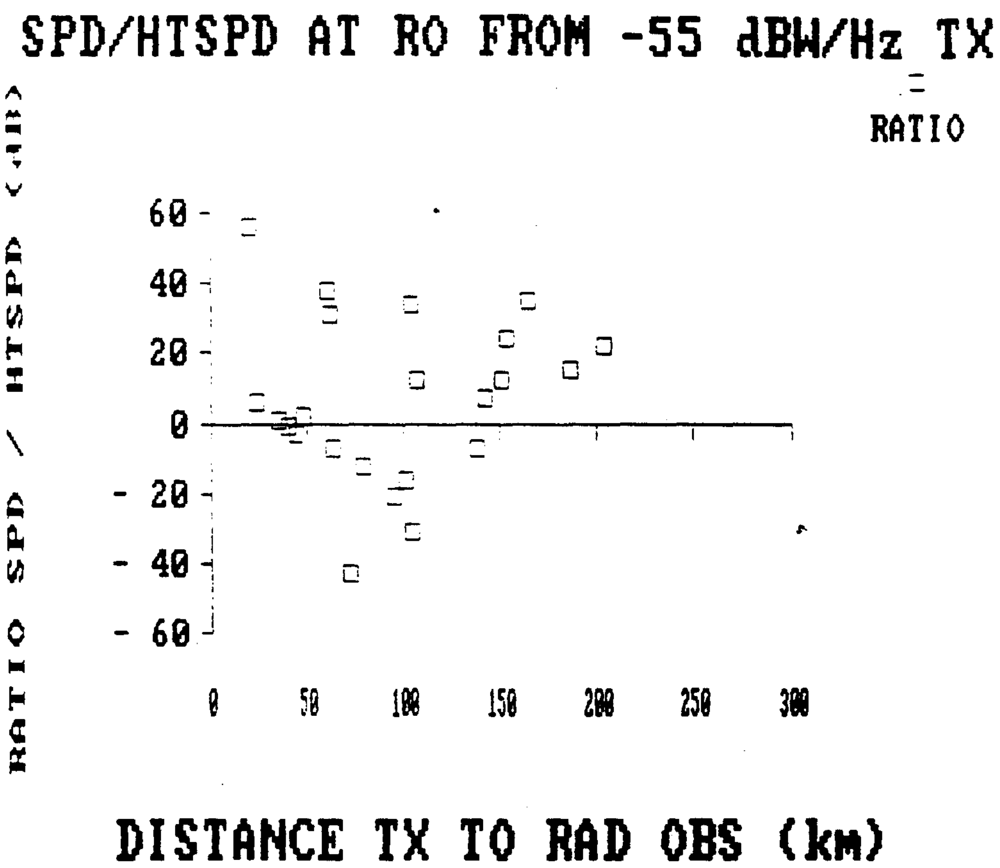

Figure 5-1. SPD/HTSPD at RO from –55 dBW/Hz Tx

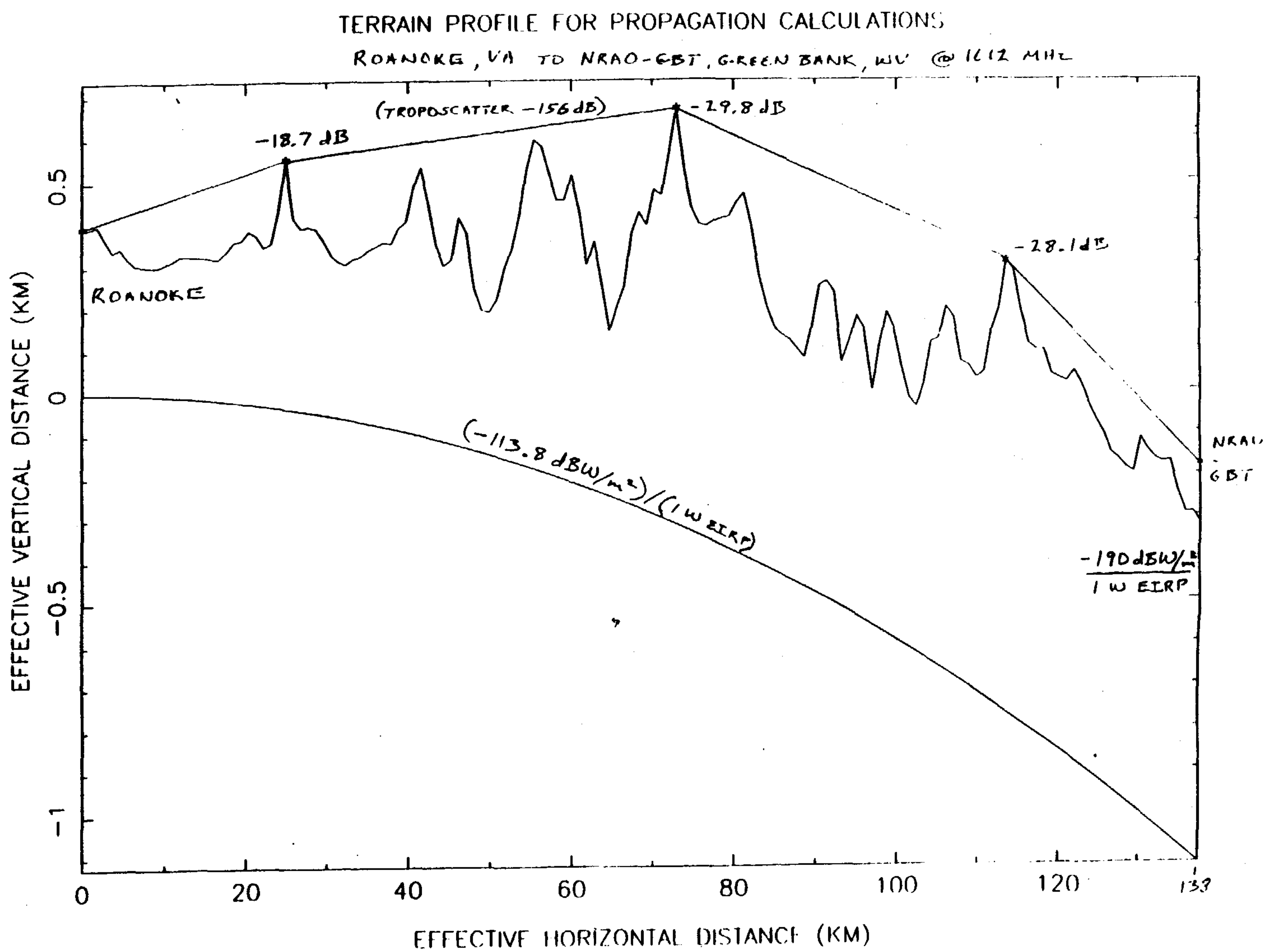

Figure 5-2. Terrain Profile for Propagation Calculations (Roanoke, VA to NRAO-GBT, Greenbank, WV at 1,612 MHz)

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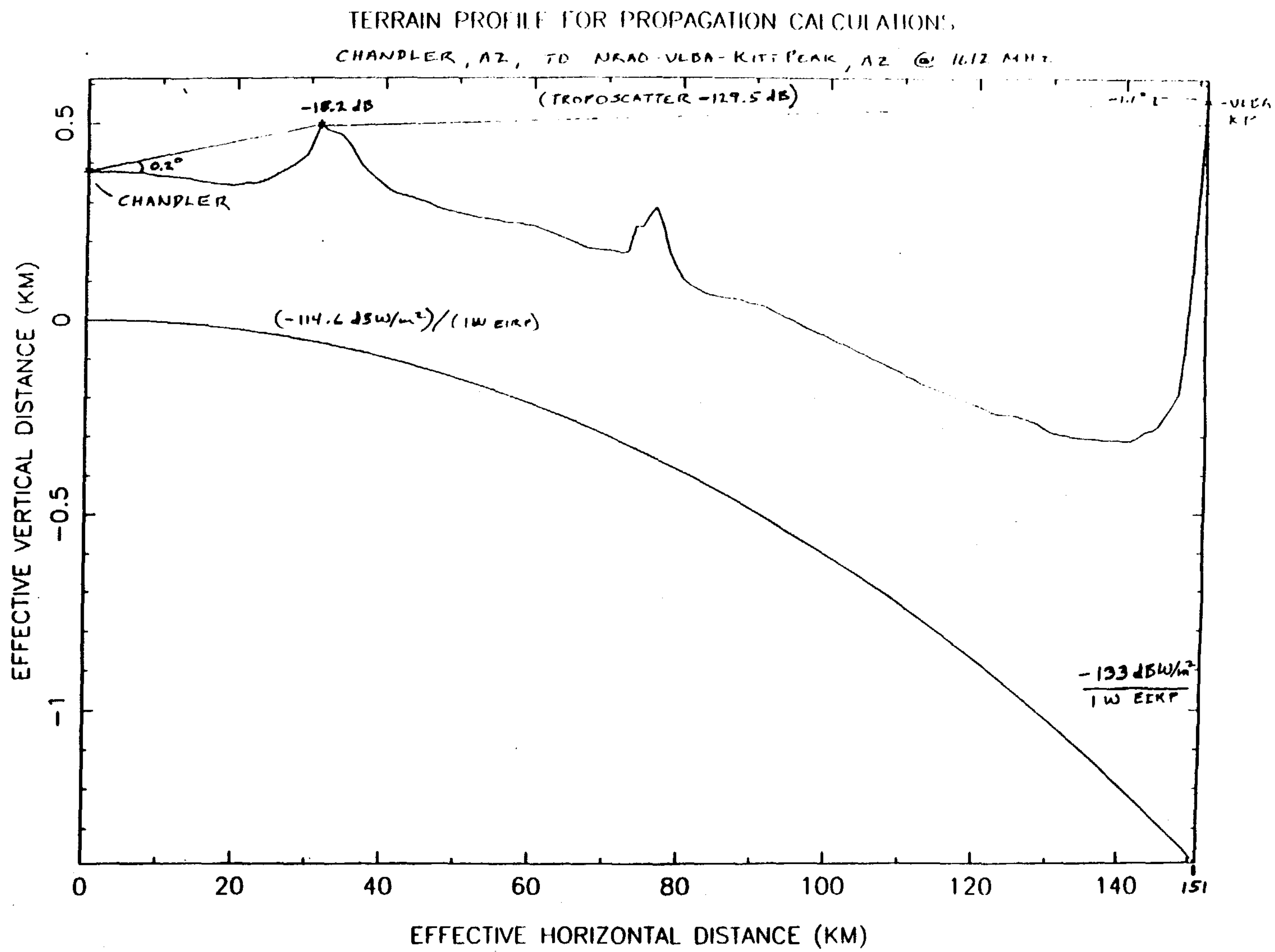

Figure 5-3. Terrain Profile for Propagation Calculations (Chandler, AZ to NRAO-VLBA-Kittpeak, AZ at 1,612 MHz)

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The preceding discussion and protection radii for radio astronomy observatories apply to terrestrial mobiles only. Exclusion zones for aircraft mobile stations will have to be based on line-of-sight distances. The radio horizon d of an aircraft flying at a height h is given approximately by:

$$d = 4.1 \times \text{square root}(h)$$

Where *d* is in kilometers, and *h* is in meters. This expression uses an effective Earth radius which is four-third (4/3) times the actual radius. Troposheric scatter may increase this distance further, but as a first approximation this formula provides the radius of the exclusion zone for co-channel transmitters, flown at height h.

As noted previously, the radius of the exclusion zone required to protect radio astronomy observatories from IRIDIUM and/or other MSS uplink transmissions outside the band 1,610.6 to 1,613.8 MHz depends, among other things, on the magnitude of out-of-band emissions. An estimate of the radius of the exclusion zone cannot be given until this quantity becomes known.

5.1.2 Fixed Protection Zones for MES Out-of-Band Emissions

One of the methods proposed to protect radio astronomy sites from MES out-of-band emissions (including spurious in this discussion) in the 1,610.6- to 1,613.8-MHz band is to employ fixed protection, or exclusion, zones. These zones would be based upon path loss calculations for each systems' relevant operating characteristics, such as, frequency plan and out-of-band emission levels. An alternative approach would be to develop a chart relating separation distance from a radio astronomy site as a function of the MES emission level that would fall in the radio astronomy band. Either approach would only be utilized during periods of observations within the 1,610.6- to 1,613.8-MHz radio astronomy band.

5.1.2.1 Over-the-Horizon Propagation Loss Calculations

LQSS has requested Comsearch of Reston, Virginia to perform path loss calculations around the Green Bank, West Virginia radio astronomy site. The following presents some of the results of this analysis.

In the spectrum management industry, over-the-horizon (OTH) loss models are relied upon heavily to assist in clearing interference cases between existing and proposed systems. Many models in use today are in some way based on the National Bureau of Standards Tech Note 101 (TN101). Comsearch uses a model based on TN101 in the day-to-day business of engineering point-to-point microwave and satellite systems. Over the last 20 years, they have worked together with AT&T, Bellcore, and organizations such as the National Spectrum Managers Association (NSMA) to refine the different implementations of TN101 in order to provide reliable OTH loss predictions. The successful implementation of this type of modeling has greatly enhanced frequency reuse factors in the microwave bands as is evident by the thousands of interference free microwave systems in operation today.

A second model that is also used heavily but more in the lower microwave bands is the Terrain Integrated Rough Earth Model (TIREM). [Note: Report Number NTIA/DF-83/001, Master Propagation System User's Manual, William E. Frazier (Coordinator).] The TIREM model uses terrain profiles to compute basic transmission loss in the frequency range of 40 MHz to 20 GHz and considers both groundwave and tropospheric scatter modes of propagation. The effects of atmospheric absorption are also considered. For the calculation process, the model examines the terrain profile to determine the radio horizon distance, effective antenna heights, and path angular distances. Refractive effects of the earth's atmosphere are accounted for by using an effective earth's radius. With these parameters identified, an initial mode of propagation is selected. These are line-of-sight and weighted combinations. Once the basic transmission loss is calculated, then the predicted loss for a given time percentage and confidence level can be determined.

The TIREM model was used in the analysis of propagation losses between a proposed Globalstar MES user and a radio astronomy site.

5.1.2.2 Example Exclusion Zone Calculation

The relevant Globalstar MES characteristics from Table 4-1 and IWG2-11 are summarized as:

MES EIRP: -4 dBW average (0 dBW during talker activity)
MES Channel Bandwidth: 1.25 MHz
MES EIRP density: -61 dBW/Hz during talker activity
MES out-of-band (OOB) emission suppression levels: -45 dB out to ±4.5 MHz from center frequency; -70 dB beyond ±4.5 MHz.

The desired spectral power flux density protection level at the Green Bank, West Virginia radio astronomy site is –238 dBW/m^{2}Hz per MSS system, or a spectral power density of -263.6 dBW/Hz at 1,612 MHz. Therefore, a propagation loss of –61 dBW/Hz to (263.6 dBW/Hz) or 202.6 dB is required to meet the objective for a single co-frequency MES user. For the out-of-band MES emissions the path loss objectives become 157.6 and 132.6 dB for the -45 and -70 dB suppression levels, respectively. Calculations were based upon a predicted loss for 80 percent of the time with a 95 percent confidence factor. The minimum path loss for these conditions was used in determining the potential interference locations. In summary, there is a 95 percent confidence level that for 80 percent of the time the path loss will not be less than the calculated value.

The nominal Green Bank, West Virginia radio astronomy site parameters used in the analysis were:

Latitude: 38° 26' 08"
Longitude: 79° 49' 11"
Terrain: Hilly, site is located in the Monongahela National Forest
Site Elevation (Ground Level): 825 m (2,707 ft)
Feed Elevation: 25-m (82-ft) above ground level.

For Globalstar MES user channels where the -45 dB OOB suppression level and frequency band applies, potential interference locations were determined and are shown in Figure 5-4. (Note: The computer based analysis was based upon an EIRP of 20 dBW and not 0 dBW which is why signal levels appear 20 dB higher on the figures.) It appears that a single MES user could operate beyond a 10-mile radius from the site. Most of the isolated interference locations are located on hilltops and not close to roadways or towns.

Similar calculations were performed for Globalstar MES user channels where the -70 dB OOB suppression level and frequency band applies, potential interference locations were determined and are shown in Figure 5-5. For this case it appears that a single MES user could operate beyond a 7-mile radius from the site, and, in some locations, to within about 3 miles of the site. A preliminary calculation indicates that about 100 MES users could operate up to a radius of about 15 miles from the site.

This example provides only an approach to determining exclusion zones for an MSS system and is not intended to be an actual determination of the protection radius. In an actual simulation, the latest available version of the TIREM model should be used, along with appropriate parameters (e.g., 100-m elevation for the feed of the Green Band telescope, 10-percent interference probability level, etc). Further, in order to take troposcatter propagation appropriately into account, model calculations have to be run well over the radio horizon, out to the 150- to 200-mile range.

5.1.3 Beacon Actuated Protection Zone

5.1.3.1 Purpose of Beacon Protection System

A beacon actuated protection system offers a method of dynamically protecting (in real time) electromagnetic sensitive locations, such as radio astronomy sites, from MSS mobile terminal (MES) uplink transmissions. Since it is not feasible to restrict the location of the MES and since RAS sites do not make observations in the 1,610.6- to 1,613.8-MHz band all the time, a beacon protection system appears to offer significant advantages over other potential RAS sharing solutions.

However, there are several theoretical and practical concerns which must be worked out before a beacon system can be implemented as an alternative to protection zones of specified radius around designated radio astronomy observatories.

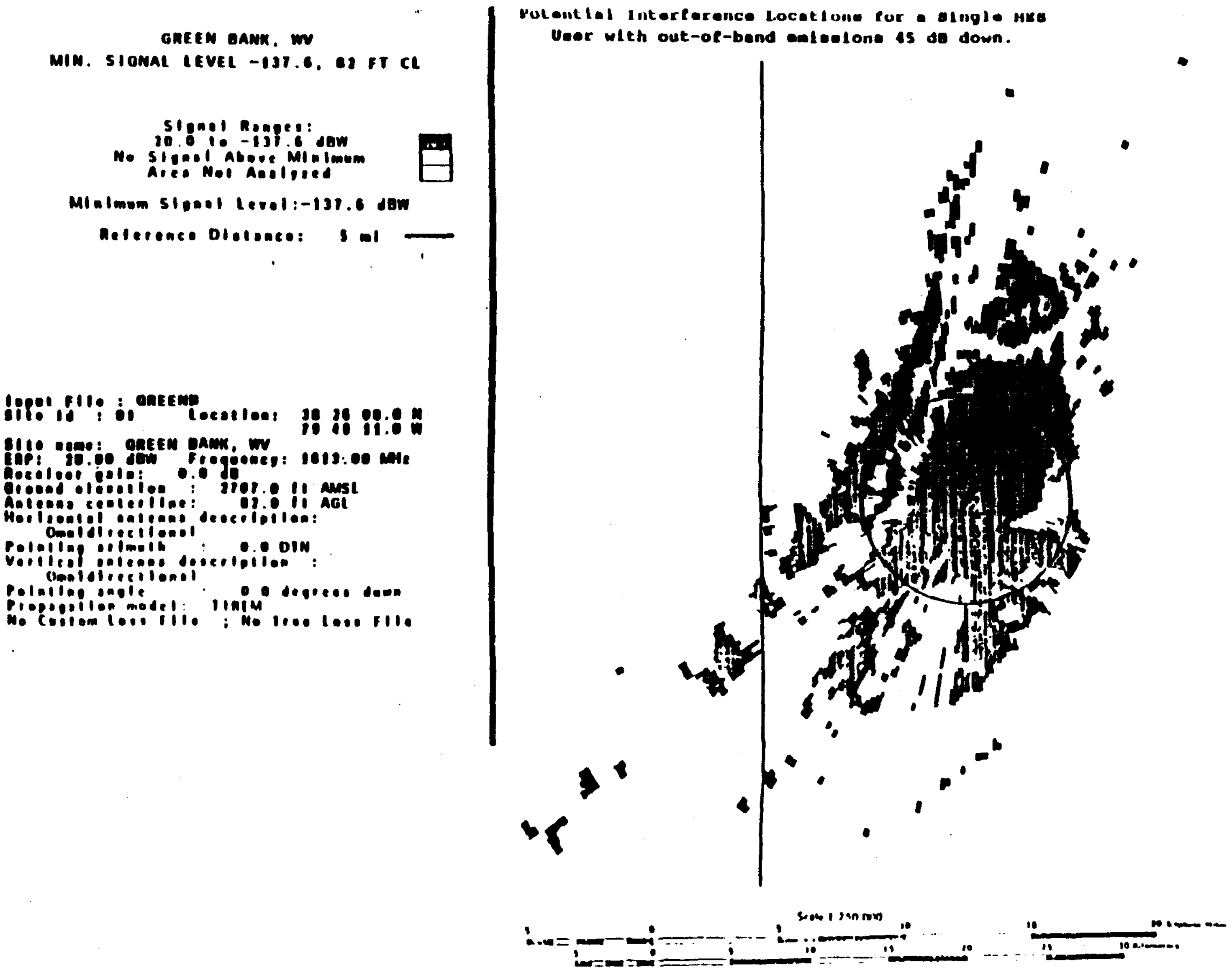

Figure 5-4. Potential Interference Locations for a Single MES User with Out-of-Band Emissions 45 dB Down

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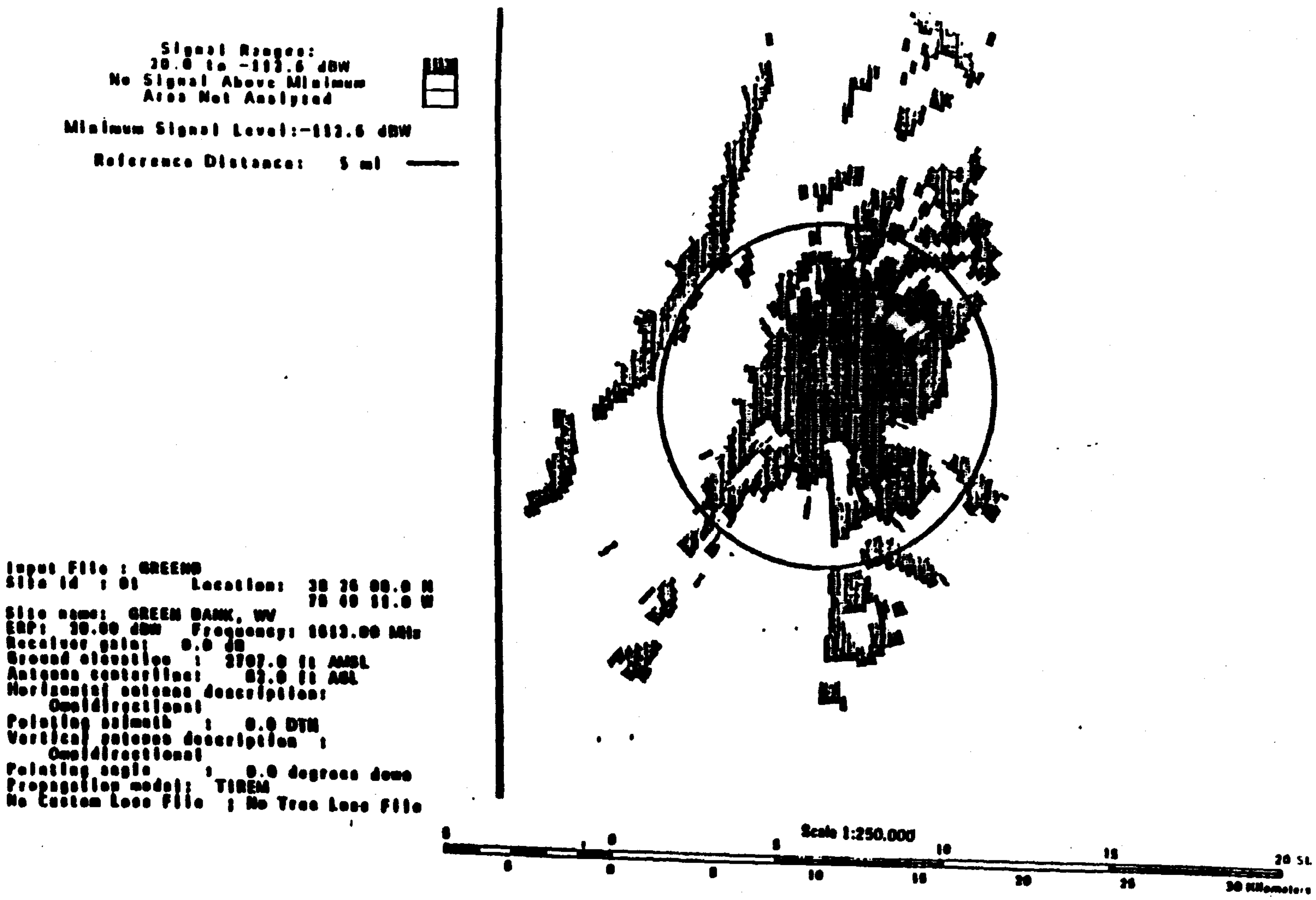

Figure 5-5. Potential Interference Locations for a Single MES User with Out-of-Band Emissions 70 dB Down

5.1.3.2 Description of Beacon Protection System

One or more omnidirectional radio beacons could be placed near each radio astronomy site that will be conducting observations in the 1,610.6- to 1,613.8-MHz band. These beacons would only transmit a signal when such observations were in progress. The number of beacons needed at each site would depend on the location of the site and surrounding conditions. Some RAS sites could be equipped with just one beacon, while other sites might need two or more beacons in order to ensure that local conditions were not masking potential interference into the RAS antenna, see Figure 5-6.

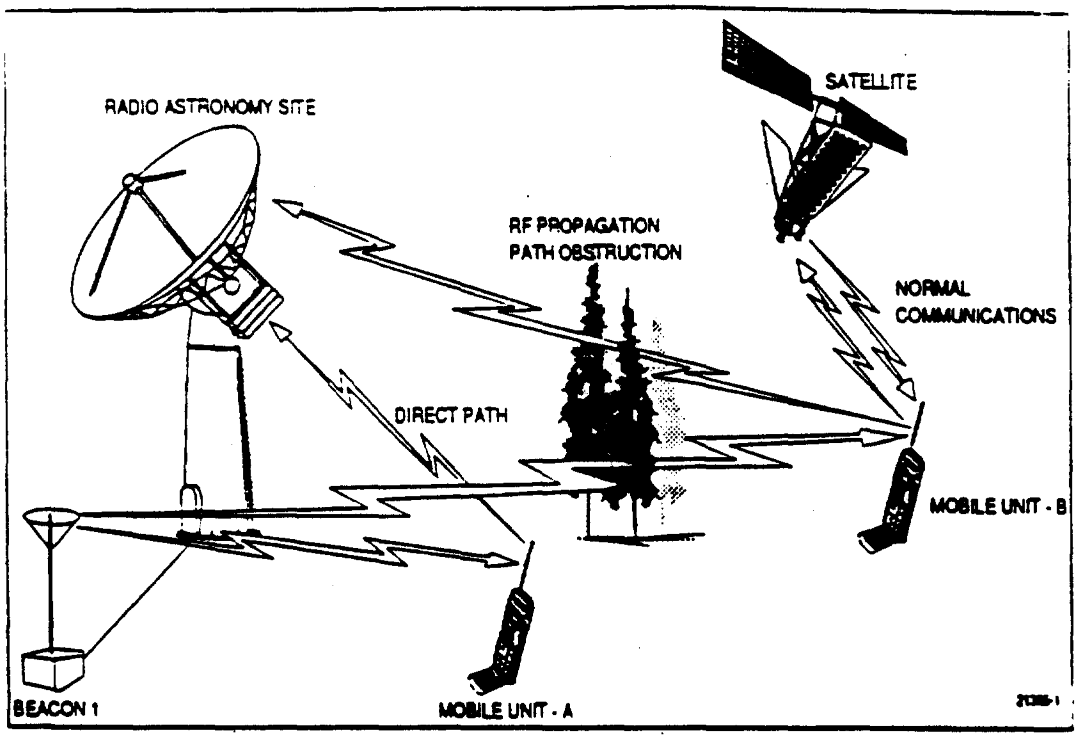

Figure 5-6. Typical Protection Beacon Configuration

When first requesting a channel assignment from the MSS Control Center on the control channel (which is not in the shared and protected band) the MSS Control Center would determine whether there are any radio emission restrictions associated with RAS observations in that area. If not, the MES would be assigned a communication channel without any restriction on the use of frequencies. If restrictions are in effect in the area of the MES, and the MES receives a beacon signal, the MSS control center would assign the MES a communications channel outside the shared, protected band. Absent receipt of such a signal, MES channel assignment would again be made without restriction. For example, if the mobile unit is shielded from the beacon by propagation obstructions (e.g., intervening terrain), then it would not receive a beacon signal and transmissions would continue without restriction. In that event, the mobile unit would be able to communicate with the satellite on any channel, and the radio astronomy site would not be affected.

On the other hand, if the mobile unit receives a beacon signal, transmissions over certain frequencies may be automatically inhibited or the system control facility may decide when transmissions would be acceptable. Alternatively, the mobile unit could be equipped to measure the power of the beacon signal and compare it with an appropriate threshold level. If the measured power level is above the appropriate threshold, the mobile unit would be automatically inhibited, or could be switched to a different frequency to prevent interference. Depending on the characteristics of the satellite system, a "beacon received" message could be incorporated in the header message of a mobile unit, and thereby notify the control center that a particular terminal is subject to emission control.

5.1.3.3 Implementation of Beacon Protection System

A beacon protection system could be implemented in a number of ways to control potential interference from MSS uplink operations. The particular beacon signal formats and frequencies are a function of the MSS system design and the site to be protected. An MSS operator intending to rely upon a beacon protection approach should be required to demonstrate that its mobile units can reliably detect such beacon signals, that they can signal reception to a system network control center and that the control center can prevent the assignment of any channel within the RAS band to the mobile units near an RAS site. A mobile unit also must have the capability to switch frequencies or shut down within a short, and specified period of time after a beacon signal above a specified level is received.

Each beacon would transmit a calibrated RF protection signal to all MSS mobile units in the general area. The beacon signal should only be strong enough to close a link with an MSS mobile unit at a sufficient distance to avoid harmful interference from uplink operations. On the other hand, the beacon signal should not be so strong as to unnecessarily restrict MSS operations. In practice, such signal strengths should be based upon expected propagation conditions and equipment parameters (e.g., transmitter antenna patterns and height, shadowing losses, carrier frequency, etc.), the electromagnetic sensitivity of the RAS sites, the transmitted power of the MSS mobile units and applicable modulation processes.

The beacon signal could be operated both in the L-band and the S-band. L-band beacon transmissions would more closely match the propagation properties of the MSS uplinks. Such operations would require an L-band receiver in the MSS mobile unit and utilize a beacon channel sufficiently removed from the RAS band so as not to cause unacceptable levels of interference to RAS observations. If a particular MSS system did not employ bidirectional operations in the L-band or otherwise did not have an L-band receiver in its mobile units, then an S-band beacon could be employed. The signal strength of an S-band beacon would have to account for the different and varying propagation properties between the L-band uplinks and S-band beacon signals.

Emergency capabilities could be built into any MSS system in order to override the beacon protection if the need for emergency communications arises while in a protection zone. Such emergency overrides would be subject to control by the management element of the satellite system.

5.1.3.4 Potential Advantages of Beacon Protection System

A beacon protection system may offer several potential advantages over other proposed sharing techniques. It may provide for adequate protection to RAS sites during periods of observations (i.e., when the beacons are turned on), while affording the flexibility of MSS terminals to operate virtually without restriction during other periods of time (i.e., when the beacons are turned off). A beacon system may also minimize the geographic protection areas around RAS sites during periods of observation by utilizing real RF boundaries in all directions. If an MSS terminal does not receive a beacon signal due to propagation losses or other real-world effects, then it will be able to uplink in any frequency channel. On the other hand, the reception of a beacon signal by an MSS terminal would only restrict that terminal's use of certain uplink channels during the period of time that the beacon remained on, or the user moved out of range. The signal strength of the beacons could also be adjusted over time to reflect additional or reduced protection requirements as circumstances warrant.

5.2 MSS/RDSS Downlink Sharing

5.2.1 Downlink Operations in the L-Band

The Commission has proposed a secondary downlink allocation in the space-to-Earth direction for the 1,613.8- to 1,626.5-MHz band in accordance with the results reached at WARC-92. This allocation is adjacent to the proposed primary RAS allocation. Only one of the current applicants—Motorola—has proposed to use this secondary L-band downlink allocation. Specifically, Motorola's IRIDIUM system proposes operating in the 1,616- to 1,626.5-MHz band on a bidirectional basis, see Figure 5-7.

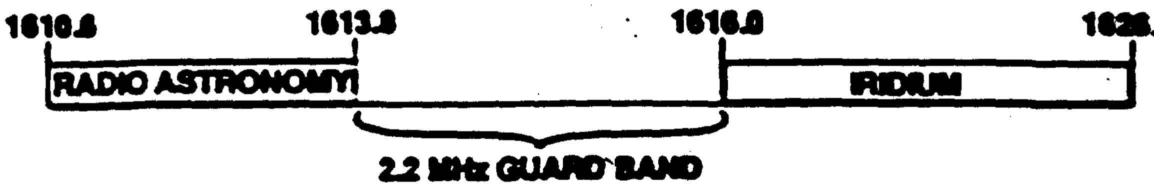

Figure 5-7. Radio Astronomy Compatibility

Motorola will adequately protect RAS from any harmful interference caused by IRIDIUM system downlink operations. The various techniques and programs proposed by Motorola to avoid harmful interference to RAS include:

- band separation and guardbands

- controlled out-of-band emissions
- a comprehensive analysis and testing program
- international coordination.

5.2.1.1 Band Separation and Guardbands

The principal means that Motorola will employ in order to protect the RAS is band separation. There will be a minimum guardband of at least 2.2-MHz between the IRIDIUM system downlinks and the RAS band. This guardband should be sufficient to prevent any harmful out-of-band emissions into RAS sites from IRIDIUM system downlinks.

5.2.1.2 Controlled Out-of-Band Emissions

Out-of-band emissions from IRIDIUM satellites will be controlled by a combination of filtering techniques and the control of downlink power. The filters on board the satellites will significantly attenuate the downlink signals outside the intended band of operation. In addition, Motorola selectively can control the number of downlink channels near the bottom of the band during radio astronomy observations.

5.2.1.3 Analysis and Testing Program

Motorola has initiated an analysis and testing program to confirm that the above steps will ensure compatibility between the IRIDIUM system and the RAS. Representatives of the Radio Astronomy community have agreed to cooperate with Motorola in conducting this test program.

5.2.1.3.1 Analysis Phase

Motorola and representatives from the Radio Astronomy community have already participated in several technical meetings to address RAS compatibility issues. Among other matters, these discussions have led to the development of several technical approaches for coexisting in the 1,610- to 1,626.5-MHz band, including the beacon protection zone concepts noted in Subsection 5.1.2 of this report.

5.2.1.3.2 Testing Phase

Motorola will be conducting field tests in cooperation with the Radio Astronomy community. The Radio Astronomers have already indicated that they will permit such testing at Radio Astronomy receiving sites. This program will be conducted using aircraft to simulate satellites, experimental satellites, and user terminal simulators. Motorola will be able to measure transmission levels at RAS sites under a variety of conditions, and will take the findings into account, if necessary, in the design of the system.

5.2.1.4 International Coordination

At WARC-92, it was agreed to add a new footnote to accompany the secondary MSS downlink allocation in the L-band. Footnote 731F requires that such operations be notified and coordinated with other services in the 1,610- to 1,626.5-MHz band, including RAS, in accordance with ITU Resolution 46. Based upon the foregoing techniques and programs, it is anticipated that coordination can be achieved between the IRIDIUM system downlinks and the RAS in the L-band.

5.2.2 S-Band Downlinks

There has been concern raised by the Radio Astronomy community over the S-band downlink second harmonic transmissions from any MSS satellite. The Committee on Radio Frequencies (CORF) has proposed radio astronomy protection levels for the MSS systems. The second harmonic of the MSS S-band satellite transmissions would overlap the radio astronomy band at 4,990 to 5,000 MHz. The required spectral power flux density protection level over this 10-MHz band is –241 dB(W/m^2Hz).

Since the pfd of MSS satellite transmissions in the 2,483.5- to 2,500-MHz band will be on the order of -142 dB(W/$m^2$4 kHz) for angles of arrival greater than 25° per RR 2566, this results in a spectral PFD of -178 dB(W/m^2Hz). Therefore, the second harmonic transmissions levels must be down at least 63 dB from the primary transmission levels. Each MSS system's desired level of rejection may be different due to different operating levels. However, the desired level of rejection should be attainable by proper S-band amplifier device selection and operating conditions plus post amplifier filtering. The feasibility of meeting desired rejection level is discussed in the following subsections.

The same criteria would also be applied to those beams providing coverage at angles of arrival less than 25° where the PFD limit is lower. Meeting the radio astronomy interference objective will be easier for these satellite beams.

5.2.2.1 S-Band Amplifier Second Harmonic Rejection

Today's S-band (2,500 MHz) solid-state amplifiers in multicarrier operation can provide 40 dB of second harmonic rejection. Depending upon operating levels and desired efficiencies, the second harmonic rejection would typically be at least 20 dB.

5.2.2.2 S-Band Output Filters

The S-band output filter could provide rejection of amplifier harmonics as well as receive bands, and adjacent channels. A typical six pole filter could provide the performance level as follows:

Center Frequency:	2,500 MHz nominal
Usable Bandwidth:	18 MHz
Insertion Loss:	0.4 dB
Second Harmonic Rejection:	70 dB minimum

5.2.2.3 Composite Second Harmonic Rejection

The above values are representative of component designs which may or may not be utilized in the design of each MSS system. Size, weight, power, and cost will be important parameters in evaluating the component and combined filter and amplifier second harmonic performance levels. For most designs these will probably be the predominate component characteristics to consider. Based upon the above discussion, meeting the desired level of second harmonic rejection within the MSS satellite appears to be a realistic objective.

Section 6
Conclusions and Recommendations

Protection of the radio astronomy service from interference from MSS/RDSS could be provided for in the Commission's rules in two ways: one would be to require coordination between prospective operators of MSS/RDSS systems and the radio astronomers individually or collectively; the other would be the incorporation of reasonable, feasible, specific, universally applicable, interference levels and separation distances or beacon actuated protection zones in the Commission's rules.

Coordination has been successful in the case of certain radiocommunication services, but this Advisory Committee believes that coordination, by itself, should not be the method used to control MSS/RDSS interference to radio astronomy.

Coordination has been successful in cases of intraservice sharing where: the susceptibility of systems in the service to interference is similar, and their ability to cause interference is also similar and on some occasions the operators will be requesting consent for establishment of a system of their own, and at other times will be entertaining requests from other operators to establish their systems. Thus, there is present both an element of technical homogeneity and a built-in incentive to be accommodating to the requests of other operators. An operator knows that at some future date they may be requesting concurrence from the same operator that is requesting their cooperation now.

Microwave radio relay systems, VHF/UHF mobile radio systems, and satellites in the fixed-satellite service are good examples of the success of coordination. Coordination of satellite earth stations with terrestrial microwave radio systems has also been successful, even though this is an instance of interservice sharing, and the susceptibility of systems to interference in the two services differs greatly Coordination has been successful largely because of the realization that a terrestrial radio relay operator that tries to block the installation of an earth station may, in future, seek permission of that same earth station operator for the coordination of a radio relay station in the same or distant part of the country.

However, such commonality of interest and homogeneity of technical characteristics does not exist between MSS/RDSS and the Radio Astronomy service. Radio telescopes are much more sensitive than MSS/RDSS systems, and RAS can only receive interference: they will never need to seek approval of MSS/RDSS operators to transmit.

If coordination were to be required in the case of downlink sharing, each prospective MSS/RDSS operator would have to coordinate with every one of the many Radio Astronomy sites, and the most restrictive coordination agreement would govern the design, construction and operation of all satellites to be launched by that operator.

Coordination is a time-consuming, expensive, uncertain process. On the other hand, the establishment of reasonable, universally applicable, and specific interference levels and separation distances, will enable all operators to design systems to known standards without the necessity for discussion of their system designs with a multiplicity of potential interference recipients.

There is ample precedent for the adoption of limiting power flux-densities to protect terrerstrial services from satellite emissions: adherence to the PFDs in Article 27, Section II of the ITU Radio Regulations (which have all been incorporated in the Commission's rules) permit satellite systems to be designed and to be operated without causing harmful interference to terrestrial services and without requiring coordination with any of the many operators of systems in those services.

Considering all of the above, the IWG 2 concludes that each RAS designated for protection must inform Electromagnetic Spectrum Management Unit (ESMU), National Science Foundation, Washington, D.C. 20550 of the period(s) during which it intends to make observations in the band 1,610.6 to 1,613.8 MHz. The ESMU must provide a current, consolidated list of observatories and their proposed operating periods to the Commission and to system operators. The ESMU should also endeavor to establish a computer-based information system that would enable system operators to ascertain observation times at individual observatories automatically. Individual radio astronomy sites, or the ESMU acting on their behalf, shall discuss the proposed schedule of operations with MSS system operators and endeavor to avoid periods of high MSS system usage to the greatest extent practicable.

6.1 MSS/RDSS Uplink Sharing, Conclusions and Recommendations

6.1.1 Fixed Protection Zone for In-Band MSS/RDSS Uplink Transmissions

The IWG 2 concludes: 1) that a protection zone of 100 mile (160 km) radius around the Arecibo, PR, Green Bank, WV, VLA (San Augustin, NM), Owens Valley, CA, Ohio State University, OH radio astronomy observatories listed in Section 3, Table 1, and any others subsequently added under the provisions described below, will protect them from unacceptable interference from uplink transmissions from MES in the band 1,610.6 to 1,613.8 MHz; and 2) that such a protection zone be incorporated in the Commission's rules.

The IWG 2 also concludes: 1) that a protection zone of 30-mile (50-km) radius around the VLBA observatories listed in Section 3, Table 1 of this report, and any others subsequently added under the provisions described below, will protect them from unacceptable interference from uplink transmissions from MES in the band 1610.6 to 1613.8 MHz; and; 2) that such a protection zone be incorporated in the Commission's rules.

The IWG 2 also concludes that RAS may be deleted from the list of protected sites upon publication of an FCC Public Notice, and added to the list of protected sites one year after publication of such a public notice, following notification to the Commission of such additions and/or deletions, by the Electromagnetic Spectrum Management Unit (EMSU), National Science Foundation, Washington, D.C. 20550, except that the Radio Astronomy observatories within 100 miles of the 100 most populous urbanized areas as defined by the U.S. Census Bureau at the time, shall not be added to the list of observatories that must be protected.

System operators should be required by the Commission's rules to include in their applications analyses to demonstrate that MESs in their systems in, or entering into, a protection zone will be detected within 1 position fix and assigned, or reassigned, a noninterfering communication channel outside the band 1,610.6- to 1,613.8-MHz.

The radius of the protection zone, around an observatory, perhaps as a function of azimuth, could be reduced (never increased) by coordination with the operator of that observatory, or by the use of a beacon actuated protection zone as summarized in Subsection 6.1.3.

6.1.2 Fixed Protection Zone for Out-of-Band MSS Uplink Transmissions

The IWG 2 concludes that fixed protection zones should be established for out-of-band MSS uplinks in the bands immediately adjacent to the 1,610.6 to 1,613.8 MHz band with radii smaller than those for in-band cases given in Subsection 6.1.1 above, and that no protection zones are needed when uplink transmissions are located sufficiently far from the edge of the 1,610.6- to 1,613.8-MHz band, provided out-of-band emissions of the MES fall off sufficently rapidly.

The fixed protection zones for out of band emission for non-VLBA sites are determined on the hypothesis that the 100 statute mile radius is a standard for cochannel protection from MES signals with a transmitted e.i.r.p. density of -55 dBW/Hz. We note that with the assumed propagation model a power of -65 dBW/Hz will produce a flux density at the radio astronomy antenna of -238 dBW/m^2. Under some assumptions, this level could cause harmful interference, but the aforementioned standard has been agreed to as a practical criterion.

Figure 6-1 and Figure 6-2 show the variation from this transmitted power permissible as a function of the radius of the protection zone. Attenuation as a function of distance has been calculated using the Okumura propagation model for open terrain as a working hypothesis. This is beyond its normal range of validity. As better models, valid over a wider range, become available they should be used. By way of example note that if the transmitted power is 10 dB less than the reference value, then the protection zone can be reduced to about 75 miles. A cochannel reduction in power might take place by lowering the transmitter power and an out of band reduction because of filtering.

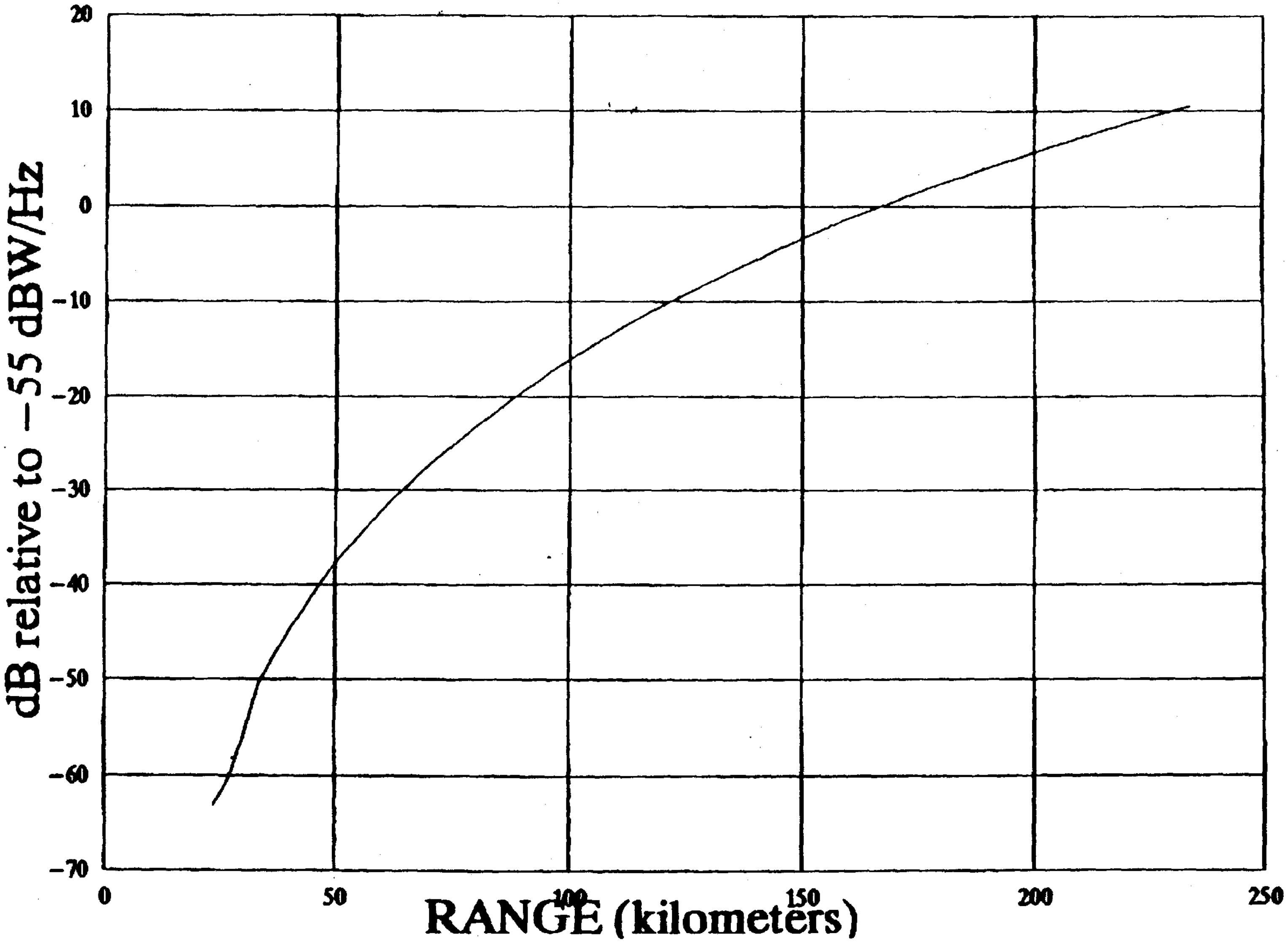

*Figure 6-1. dB Relative to -55 dBW/Hz vs 25- to 250-km Range for 167-km Radius Sites ([for r > 20 km, EIRP/Hz = 72.29 * log(r) -215.5 where r is in km] based on Okumura model for open areas)*

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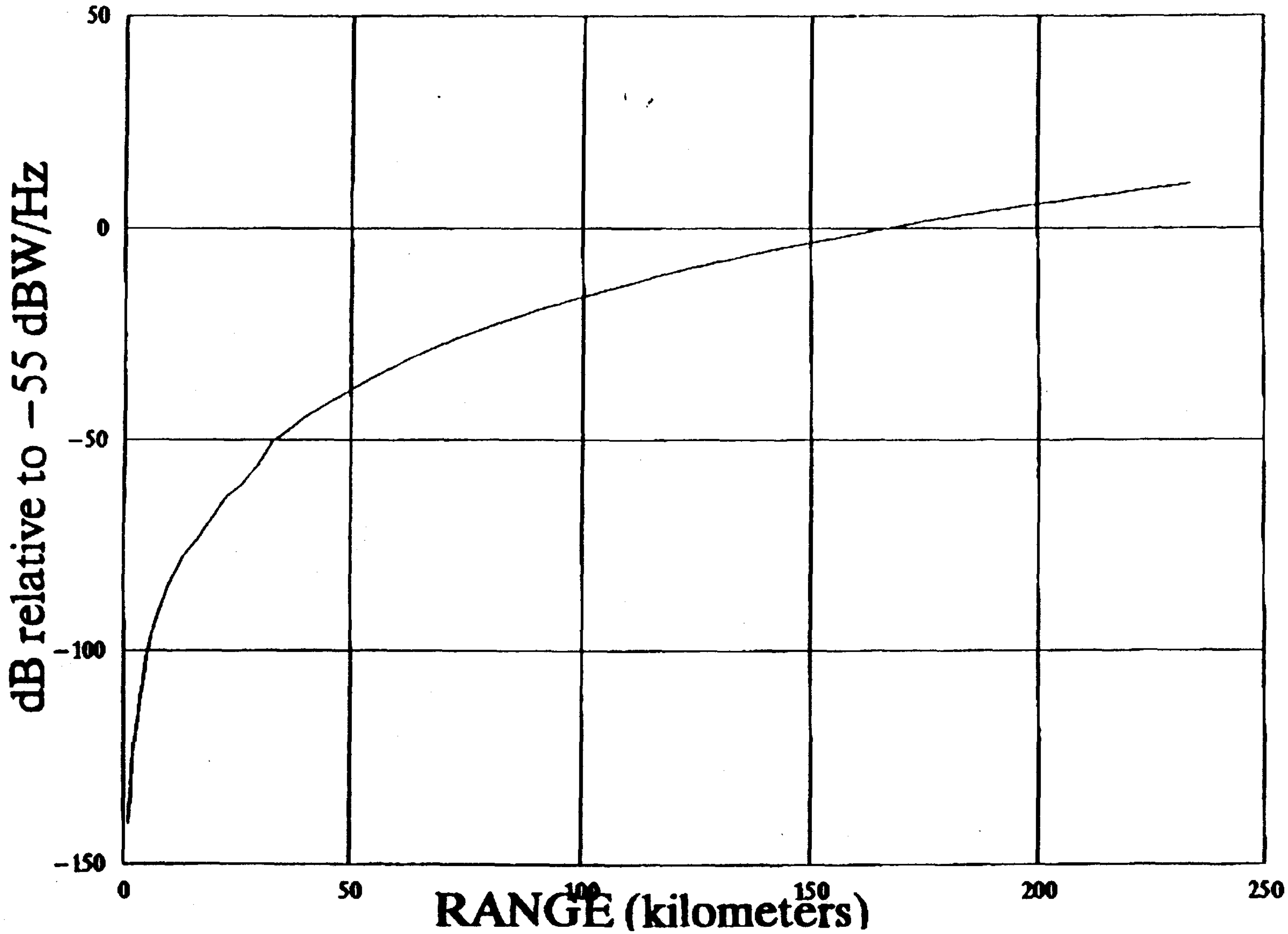

*Figure 6-2. dB Relative to -55 dBW/Hz vs 0- to 250-km Range for 167-km Radius Sites ([for r > 20 km, EIRP/Hz = 72.29 * log(r) -215.5 where r is in km] based on Okumura model for open areas)*

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Figure 6-3 shows the effects of such filtering on out of band emissions for three different, but representative, Butterworth filters. The filter and propagation curves can be combined, as in Figure 6-4, to show directly the relation between protection zone radius and frequency offset.

Note that the curves do not go below 1.0 km because the Okumura model is not valid at such short distances. However, it would be desirable to permit operation of MES, even on the grounds of astronomical observatories, if it can be shown that they will not cause interference. It is to be hoped that values for such close ranges will be proposed by one or more of the parties responding to the Commission's NPRM for MSS/RDSS systems above 1.0 GHz, which will be issued subsequently.

Figure 6-5 and Figure 6-6 are repeats of the first two figures but based on the 30-mile protection zone considered as a baseline for vey long baseline radio astronomy.

The attention of the committee is drawn to the potential impact of providing this level of protection from out-of-band emmissions on the various MSS/RDSS sharing approaches under consideration by IWG-1.

6.1.3 Beacon Actuated Protection Zone

Beacon actuated protection zones could provide an acceptable alternative to fixed protection zones for operating MES near RAS. However, the concerns discussed above must be worked out to demonstrate the practical, technical and economic feasibility of the beacon concept as an alternative to protection zones of specified radius around designated RAS. Since implementation of MSS/RDSS systems will undoubtedly take a few years, there will be time to resolve these questions.

In order for this approach to work in practice, there must be close coordination between the MSS system proponent and the RA community. Accordingly, the Commission should adopt a rule which would require any MSS licensee that proposes to rely upon such a beacon approach to coordinate its system design, testing, and operating procedures through the Electromagnetic Spectrum Management Unit (ESMU) of the National Science Foundation, CORF, or other suitable entity designated by the radio astronomy community. The Commission should also require that all parties negotiate suitable agreements in good faith and on a timely basis.

In summary, a beacon actuated protection zone could be used in lieu of the protection zone of specified radius around an RAS following coordination of the specific beacon system to be employed with the operator of that RAS.

6.2 MSS/RDSS Downlink Sharing

The list of RA observatories designated as requiring protection from emissions in the band 1,610.6 to 1,613.8 MHz may be changed from time to time. Consequently exclusion zones, or beacon protection zones, may be established or removed as

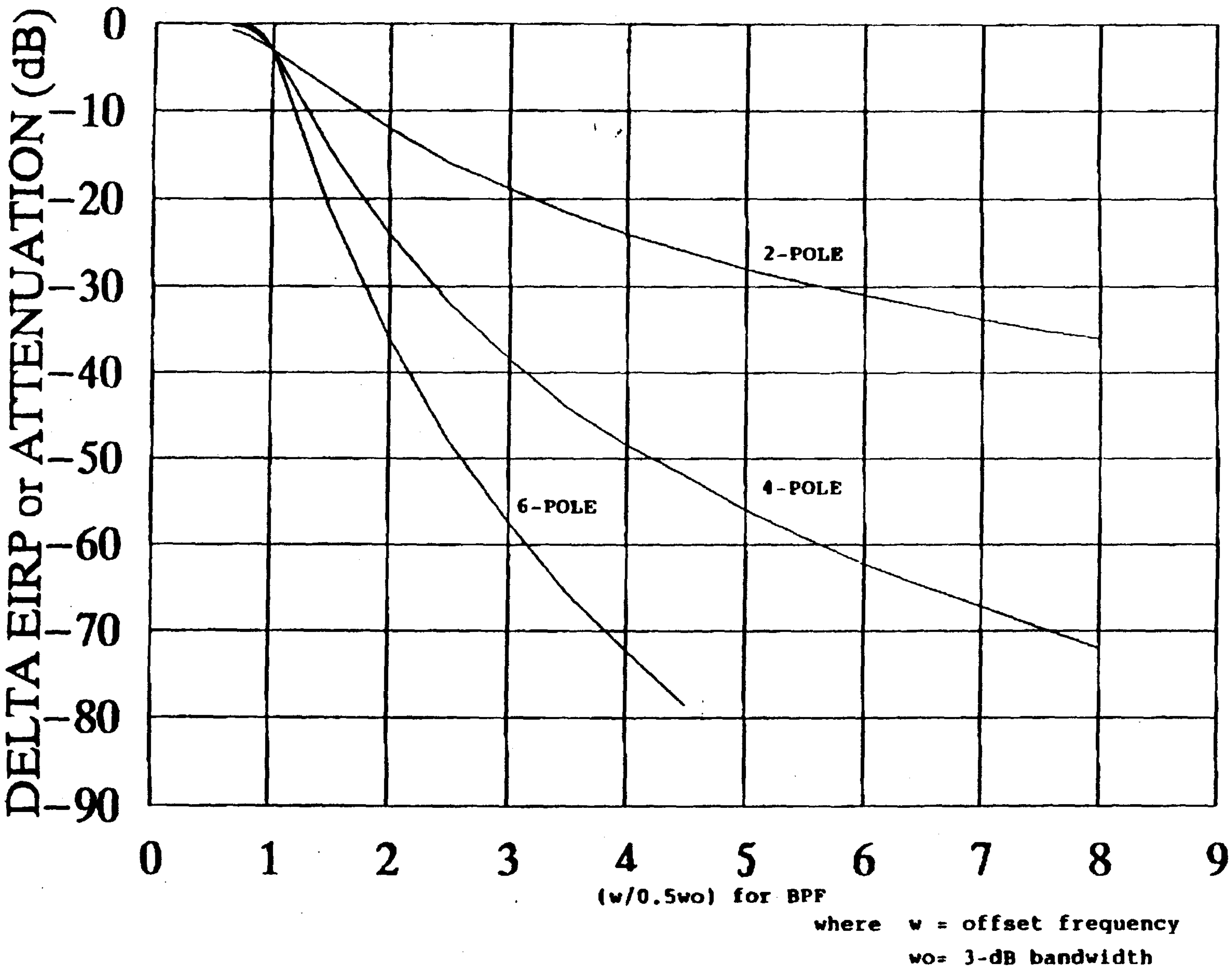

Figure 6-3. Delta EIRP or Attenuation vs ($w/0.5\ w_o$) Two/Four/Six-Pole Butterworth Filter Characteristics

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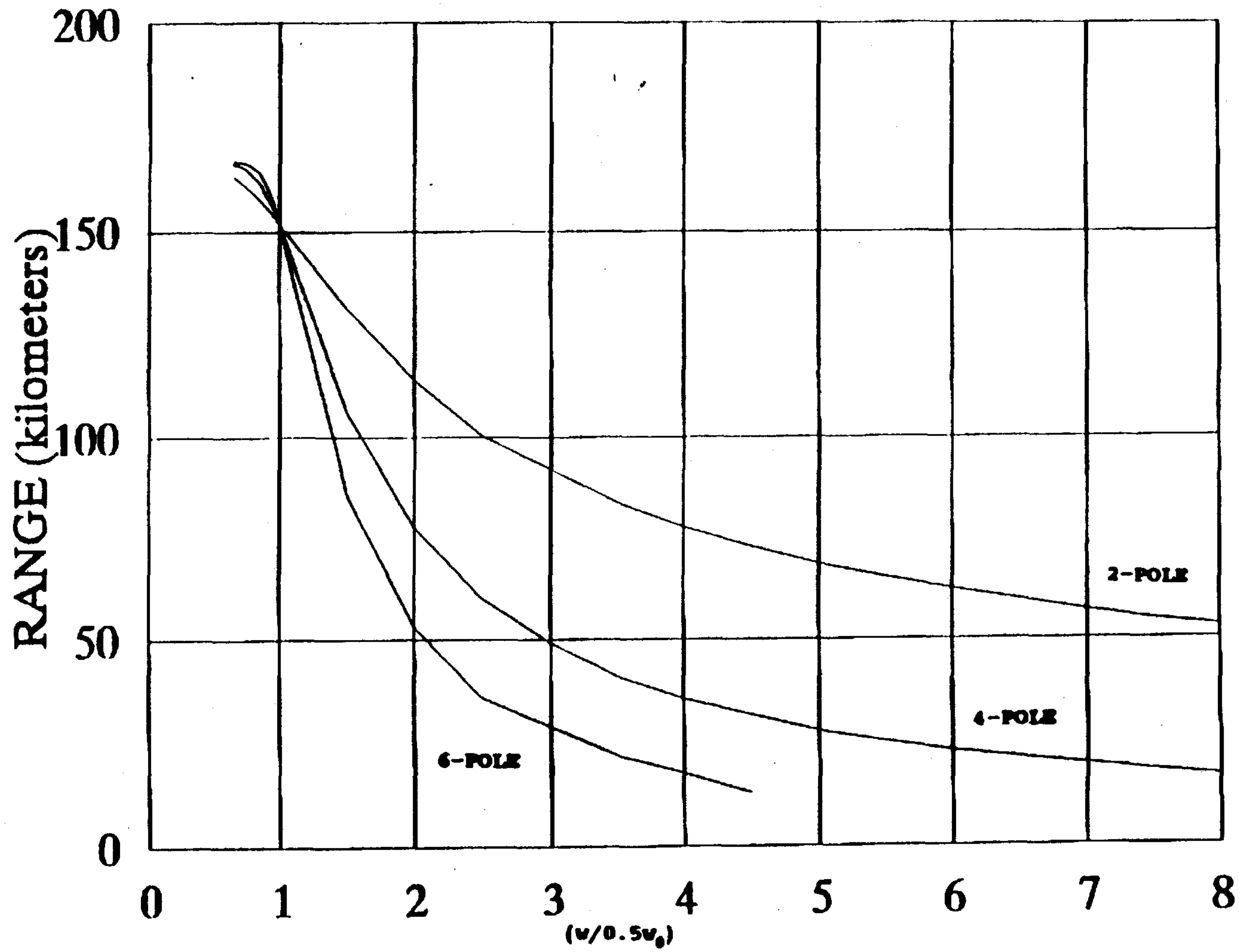

Figure 6-4. Range (Miles) vs ($w/0.5\ w_o$) for 100-mi Radius ([two/four/six-pole Butterworth filter characteristics] w = offset frequency from BPF center frequency, and w_o is 3-dB bandwidth)

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